Campbell 2. fl. (1-24)2

Boulder Committee
4th Report

1877 · 8

Mentioned to me by Prestwich as good work, while on the subject of my paper on the "Parallel Roads" & my wish sent to D. who is doing a paper for the Geological Society on the Parallel Roads.

5th January 1879

Feby 28 The Convener at Edinburgh showed me his iron boulder. It is a concretion without any marks of rolling or grinding

8

# FOURTH REPORT

OF THE

# BOULDER COMMITTEE

OF THE

## ROYAL SOCIETY OF EDINBURGH;

WITH

## REMARKS BY THE CONVENER.

*From the Proceedings of the Royal Society of Edinburgh, Session* 1877–78.

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# FOURTH REPORT

OF THE

# BOULDER COMMITTEE OF THE ROYAL SOCIETY OF EDINBURGH.

(*With 3 Plates.*)

Since the last Report was drawn out and laid before the Society, the Convener has had an opportunity of inspecting a considerable number of boulders not mentioned in previous Reports. Some of these are interesting, on account not only of size, but also of shape, marks on them, and position. The Committee consider that advantage will result from a special description of these, and from woodcuts of a few.

The cases have been arranged, as in previous Reports, according to counties, to indicate the geographical position of the boulders, and enable persons desirous of inspecting them, to know where to find them.

His Grace the Duke of Argyll, at the meeting of the British Association in Glasgow in 1876, was pleased to allude in complimentary terms to the researches of the Committee, and to express a hope that a condensed abstract of all the boulders reported on, might ultimately be framed. The suggestion will receive the consideration of the Committee.

## ARGYLLSHIRE.

1. *Glenelg.*—Blocks of grey and red granite occur in the drift-beds through which the river Elg has cut. The rocks of this district are not granite, but clay schists.

On the right side of the valley of the Elg, immediately above the road, about $2\frac{1}{2}$ miles east of Glenelg, there is a grey granite boulder, $21 \times 18 \times 10$ feet, as shown on figs. 1 and 2, Plate I. The sharp end points N.N.W. Its height above the road is 1020 feet, above the sea 1120 feet.

It goes by the name of the Macrae Boulder, in consequence of a prophecy by a Mackenzie of Kintail, that some day, when one of the clan Macrae is travelling on the road below, it will fall and crush him.

The boulder is on the very edge of a shelf of the hill, and projects beyond it about 6 feet, as shown in figs. 1 and 2, Plate I.

The rocks on which it lies are clay-stone schists. The boulder must therefore have been *brought* to its present position. It is said that on a hill some distance to the west there is a granite rock similar to that of the boulder. By what means, and how the boulder was deposited in its present precarious position, it is difficult to explain. Possibly, when deposited, there was no steep cliff, at the edge of which it now projects. The whole valley may have been filled with detritus up to the level of 1100 feet, and thereafter scooped out by the river, as the sea, in falling from one level to another, gave to the river more cutting power. This process of scooping might have continued for such length of time, that the cliff thereby formed at length reached the boulder.

2. *In Glen Rossdale* (about 8 miles from Glenelg), at a height of about 900 feet above the sea, there is a boulder of coarse red granite, $5 \times 4\frac{1}{2} \times 3$ feet, on the top of a narrow ridge of hypersthene rock, as shown on fig. 3, Plate II., on the left side of valley.

Its position also is precarious, and suggests a doubt whether, when brought here, it could have been deposited on the precise point where it now stands. There was nothing to indicate the direction from which the boulder had come.

3. There is another boulder on the right side of the valley, about 820 feet above the sea, $12 \times 15 \times 7$ feet, fig. 4, Plate I.

It lies on a shelf near the ridge of a hill, and close to a slope of the hill which rises up from the boulder, and facing the N.W. The spot suggested the idea that the boulder had been brought from the N.W., and that this hill stopped its further progress. There is towards the N.W. an opening among the hills through which it might have been floated towards its present site.

4. A little lower down the valley (Rossdale), and on the same side, at a height of about 630 feet above the sea, there is a rocky knoll somewhat flat on the top, and presenting an area of about 8 or 9 yards in diameter, on which are five or six boulders lying

pretty close together, as shown on fig. 5, Plate I. The boulders are granite, the knoll is mica schist.

5. At a still lower part of the glen there is a steep hill sloping down to the river. Near the top of this hill, and on the very edge overhanging the river, a boulder rests at a height of 300 feet above the river. The boulder is of granite, about 20 feet in diameter. It rests on mica slate rocks, which form a smooth surface sloping down towards the river at an angle of about 30°. Its position indicates transport from the north, as the land there is low enough to have allowed it to be floated over, whilst high hills to the south exclude that direction.

In the valleys where these boulders lie, there are some remarkable terraces. They were made known to the Convener by Captain Burke, R.E., two years ago, when he was still at the head of the Scotch Ordnance Survey. The surveyors employed in drawing the contour lines for the maps were struck by the horizontality and continuity of the terraces. Captain Burke was so obliging as to draw on the Convener's map lines to indicate their position. As these terraces suggest important views bearing on the position of the boulders, and their mode of transport, it seems not irrelevant to record the notes supplied by Captain Burke and give a copy of the map, to show where the terraces are.

Before, however, describing these higher terraces, it may be right to refer to certain flats at the mouths of the valleys near the sea.

The town and village of Glenelg are situated on a flat which prevails all along the Scotch coasts, about 11 or 12 feet above high-water mark. Between Glenelg and Glenbeg the base of some high rocky cliffs is at the same level.

Mr Fraser, schoolmaster at Glenelg, having learned that the Convener was desirous of seeing examples of flat land, conducted him to the following spots:—

(1.) At Glenbernera, about half a mile to the north of Glenelg, there is a well-defined flat, about 44 or 45 feet above high water. A corresponding flat occurs at many other parts of the coast.

(2.) Behind and above the new schoolhouse at Glenelg, there is a considerable extent of flat land, at a height of 72 feet above high water. On the opposite, *i.e.*, the south side of the valley, which is half a mile distant, there is a flat at exactly the same height,

judging by the spirit-level. The river has cut through this flat. Its original formation cannot be ascribed to river action.

Beyond the manse and church, there is another extensive flat, 88 feet above the sea.

In a higher part of the valley, there are terraces on a smaller scale. If they slope with the river, as they seem to do, *they* probably had been formed by the river, when it ran at a higher level, that is, when the sea also stood at a higher level than now.

Near the mouth of Glenbeg, about a mile from the sea, there is a great mass of detritus, through which the river Beg has cut its channel. There is a flat here also on each side of the river, the level of which is about 120 feet above high water.

Fig. 6, Plate I. is (from memory) a plan of this valley. The parts marked *a*, *a*, &c., are patches of detritus, the tops of which are all on the same level, or very nearly so, viz., 50 feet above the sea.

The whole valley apparently had been filled with detritus, when the sea stood at least 150 or 200 feet above its present level. As the sea retired, channels were cut in the detritus, not only by the main stream now occupying the valley, but by the numerous and rapid side streams from the steep mountains which enclose the valley on both sides.

At about 3 miles from the sea, the place in Glen Beg is reached, where Captain Burke states he noticed a horizontal terrace on both sides of the river, at a height of 330 feet above the sea. It is marked (A) on plan, fig. 7, Plate II.

The Convener recognised a terrace on the right bank at 338 feet, but he could see none on the opposite or left bank. At a little distance farther up, there are on the left bank gravel knolls at a somewhat higher level. At this place, the channel of the river is about 40 feet below the terrace, and is of rock, which has of course prevented any deeper cutting of the drift beds.

At the junction between Glen Beg and Glen Rossdale (B) in the plan, there are very large knolls of detritus with flattened tops.

From the highest of these knolls, the Convener, on looking across the valley in a direction by compass E. by N., descried a terrace, continuous for about 80 yards, and apparently horizontal. Its position is indicated on the plan by five small vertical strokes. When the spirit-level was turned in a direction about E. by S., it struck on another

horizontal terrace, about half a mile distant. All these flats are at one height, viz., 528 feet above the sea.

Higher up Glen Rossdale on the left bank, and at a spot about 1½ mile from (B), there is an extensive flat, which had been marked by Captain Burke. He states it at 750 feet above the sea. The Convener made it 760 feet. When a person is on the terrace, it is not distinctly traceable for more than 300 or 400 yards; but when viewed from the opposite side of the valley, at a distance of about a quarter of mile, it can be distinctly traced for more than a mile continuously; and at its east end it is seen to cross the ridge which divides Glen Beg from Glen Rossdale.

In a higher part of Glen Rossdale, and still on the left side of the glen, the Convener observed traces of a shelf at 853 feet, with a steep slope or bank below it of about 30 feet in height. The Ordnance surveyors observed traces of a horizontal terrace still higher, viz., at 1500 feet above the sea. The Convener, looking in that direction, observed, at a distance of about 3 miles, something like a horizontal line running for nearly a mile continuously at what might be about that height.

On the plan, Captain Burke indicates as existing in adjoining glens, traces of the 330 feet terrace by the cypher 0. These glens the Convener had not time to visit.

He has also put a X at the head of three several glens to indicate that at these places, and at a height of 750 feet, there are gravel heaps.

Some quotations may be made from Captain Burke's letter, dated 25th August 1876 :—

"I was up Glenelg yesterday. There is evidence of the sea having stood at more than one height, considerably above its present level.

"The only terrace of any consequence is in Glen Rossdale. It is about 300 yards in length. It has nothing in the least resembling Glen Roy.

"I will now answer your questions :—

1.—Height above the sea—

| | | |
|---|---|---|
| (1) | Principal terrace, about | 750 feet. |
| (2) | Another, very doubtful, . . | 520 ,, |
| (3) | Some rather more apparent, . | 330 ,, |

"This terrace, at the head of Glen Beg, affords strong evidence of a

beach, such as now exists in all sea lochs hereabouts. Beds of gravel at 330 feet are cut through by the stream running through the valley.

"On crossing the high neck, 450 feet above the sea, and descending into Glenmore, similar beds were found at the head of that valley, at the same altitude.

"The spot marked in my sketch IIIII at 530 feet is very doubtful.

"The 750 feet terrace is visible in patches in Glenbeg and Glen Rossdale. I tried to trace it down Glenmore, for I have no doubt the land between these glens was once an island. But, although I fancied I found a mound sometimes, it can't be traced.

"The longest vestige of a terrace which I saw, is in Glen Rossdale, viz., about 300 yards; for the rest, there is only a mound here and there on the hill side.

"As to the width of the terraces, the greatest I saw is about 30 yards.

"You ask how high up these hills is sand and gravel found? I saw appearance of gravel at over 1200 feet. There are gravel heaps at 750 feet at the heads of the valleys marked X, at the spots one would expect to find them, and also at ⊕, apparently washed when the country was under water, and since cut through by the streams in the valleys. In fact, all the appearance is as if these valleys were once sea lochs, just as are Lochs Nevis and Hourn at the present day. These marks are frequent throughout the Highlands. I have seen similar gravel-beds along streams in several other glens.

"Whether it will be decided to survey the shelf, I cannot say. But there is nothing definite except the bit in Glen Rossdale; and a surveyor would not find it easy, when on the hillside, to know what mounds he should show, unless he had previously run a contour at the required height.

"I have made two sketches, one of Glenbeg looking east, another of Glen Rossdale looking west, which I shall be happy to show you."

With reference to these last remarks by Captain Burke, it occurs to the Committee to express an opinion that, when the Ordnance surveyors discover on the hill sides terraces of the kind referred to, there should be some record given of them on the maps, accompanied by a contour line at the same level along the adjoining hills,

so that it might be seen whether there are separate patches of gravel elsewhere at the same height. It is also desirable that when the officer at the head of the Survey verifies what the surveyors have found, and makes sketches of the terraces, these sketches should be given with the maps when published.

In walking down Glen Rossdale valley, on the right bank, the Convener fell in with a large mass of detritus, cut up into a series of knolls by the action of streams and rain. The height of these knolls above the sea was on an average 858 feet—agreeing pretty nearly with the level of the shelf already noticed as existing on the opposite side of the valley.

These remains of gravel in Glen Rossdale and the adjoining glens, looking to the height and the form in which they occur, seem conclusive as to the occupation of these valleys by the sea; and they confirm the inference derived from the position of the boulders, that the boulders were probably *floated* into these positions.

The Convener was at first puzzled to account for the circumstance that most of the large boulders which he saw in these valleys were not upon drift, but upon bare rock; and in many other parts of the country, the same thing occurs. If these boulders were floated by ice and thrown down, they must most generally have fallen upon the detrital beds then forming the sea-bottom, and not upon bare rocks. When the sea retired, the boulders would then be on the drift, or buried in it. But when the streams from the hill sides began to flow and to remove the drift, the boulders would sink until rock was reached by them, where, of course, they would remain. The denudation of the old sea-bottoms has been everywhere so extensive, that very probably most of the boulders now existing are not in precisely the exact positions which they occupied when originally deposited.

6. *In the Pass of Brander*, where the River Awe flows out of the lake of the same name, there are several boulders deserving notice.

On the right bank of the river, near the spot where there is a pier for the small lake steamer, there are two terraces on drift. Both terraces have boulders on them. The boulders are of reddish granite. The rocks in the Pass are a slaty schistose rock like greywacke. The boulders have apparently come from some distant

region, as the granite of the Loch Etive hills is not red, but almost entirely grey in colour.

The height of Loch Awe above the sea is (by Ordnance Survey) 110 feet. The lowest terrace is 68 feet, the higher terrace about 120 feet above the loch.

Both terraces appear to be horizontal. They can be traced for nearly a mile continuously.

On the opposite or left bank of the river no corresponding terraces are distinguishable. That side of the valley consists of nearly bare rock, and is almost vertical, so that there cannot be expected to be on it any trace of a beach line.

Have these terraces in the Pass of Brander been formed by a lake or by the sea? In a lower part of the valley there is a large amount of detritus, and it reaches at some places to a higher level than the terraces. The valley in that lower part is narrow, so that there might have been a blockage for a lake. On the other hand, how can the granite boulders be accounted for which are on the terraces? If, as seems most probable, they have come from the north, they must have been floated by ice on a current flowing from the N.N.W.

7. *Inveraray.*—His Grace the Duke of Argyll (Nov. 1876) conducted the Convener to a small hill, about 1000 feet above the sea, at a place called "*Brae Leckan*," 7 miles west of Inveraray, well covered with angular boulders. The boulders were of the same nature as the rocks of the hill—a dark grey porphyry. But the boulders had evidently been transported to the hill from some other place, there being no cliff from which they could have fallen. The Duke thought they had been floated from the eastward, and in that direction certainly the land was lower than in any other direction. But the Convener observed that towards the west there was an opening among the hills low enough and wide enough for a current to have flowed to and over the hill on which the boulders rested.

8. A few miles to the *north of Inveraray* there are some huge boulders of a coarse conglomerate, quite distinct from any of the rocks in the immediate neighbourhood. The rock of these boulders is a greenish or grey coloured Silurian rock full of quartz pebbles. One of these conglomerate boulders, weighing about 60 tons, is on

flat ground about 800 feet above the sea, and resting on gravel. Another, $10 \times 9\frac{1}{2} \times 7\frac{1}{2}$ feet (weighing about 48 tons), is on the left bank of the River Arey, and about 180 feet above the sea.

The gamekeeper, who pointed out these boulders, said that there was no rock of the kind composing them, except at a place about 6 miles due west. Between that spot and the sites of the boulders there were several ranges of hills and valleys.

When the subject was mentioned to the Duke of Argyll, he corroborated the gamekeeper's statement. He informed the Convener, that there is conglomerate rock, of the same character as that of the boulders, on the summit or ridge between Loch Awe and Loch Fine, which lies to the north-west of the boulders.

On the tops of several of the hills to the north-west of Inveraray, about 700 feet above the sea, boulders were noticed where it was manifest, from their peculiar position, that they could have got into it only by coming from the west. Sketches of these were taken.

9. *Oban and Neighbourhood.*—(1.) At Dunolly, close to the sea shore, there is a grey granite boulder $12 \times 8 \times 6$ feet. It is about 20 feet above high water, and rests on an old sea beach. Its longer diameter points W. by N.

The nearest rocks of grey granite are in Loch Etive, situated to the eastward. There are ranges of hills between Loch Etive and the site of the boulder. Moreover, the boulder is close to the foot of a high rocky cliff, which being on the east side of the boulder, must have prevented the boulder reaching its site, except by transport from the westward,—probably the north-west, as the island of Kerrera is situated to the west and south-west, and would prevent the boulder coming from that direction.

The Convener was accompanied by a gentleman resident in the neighbourhood (Mr Clerk), well acquainted with the Loch Etive granite, who expressed doubts whether the granite of this boulder was of a similar composition.

(2.) The north part of Kerrera Island is strewed with numerous grey granite boulders, all well rounded. Most of them are on the beach, and on the old terraces adjoining the beach. There are some also, on Ballimore Farm, at heights of from 357 to 437 feet above the sea, on short terraces or flats of detritus facing the east and north-east.

In these cases there would be less obstruction to a transport from

Loch Etive than in the case of the Dunolly boulder, but the range of hills near Glenlonan, reaching heights of from 500 to 1500 feet, still presents a difficulty.

If the Dunolly boulder came from a northern source, the Kerrera boulders probably came from the same quarter.

(3.) On the hills to the east and north-east of Oban, there are numerous boulders, chiefly of granite, whose position does not suggest one direction more than any other.

The rocks of these hills being clay slate, the boulders on them must have been transported from some distant quarter.

The granite is grey of different varieties, and very like the Loch Etive granite. But there are others, with large crystals of quartz and felspar, which betoken some other source.

One of this kind is on a hill to the south of the old public road between Oban and Loch Etive, at a height of 530 feet above the sea. It is extremely angular, and rests on a bare rock of the hill. This position would most easily have been obtained by floating ice.

Besides these *granite* boulders there are some of *dark porphyry* and of quartzite, which most probably come from the north.

This conclusion is somewhat strengthened by the circumstance that in this district, where the rocks are smoothed and striated, the surface of the rocks slopes down towards and faces the north and the striæ run north and south. Examples occur on the old public road before-mentioned.

(4.) An angular boulder of grey granite, $11\frac{1}{2} \times 7\frac{1}{2} \times 7$ feet, occurs at Inverlievern, on Loch Etive, above Bonawe Ferry. This boulder rests on three or four smaller granite boulders, and these again on bare granite rock. There is no hill from which it could have fallen. It must have been transported. A sketch was taken.

It rests on the 40 feet old sea-margin, which is visible round the greater part of Loch Etive.

(5.) The Convener was informed of two very large boulders in the district between Loch Etive and Glen Lonan, at places called Auchnacoshen and Duntarnichan. But he was unable to reach them.

10. *Fasnacloich on Loch Creran.*—Captain Bedford, R.N., wrote to the Convener, calling his attention to a large boulder which he had seen when surveying for the Admiralty. He sent a description of it, and mentioned that its average girth was 30 feet.

The Convener discovered the boulder. It had recently been blown up into four or five fragments, with a view to being used for building a bridge. But they were found unsuited for the purpose, being too hard for masons' tools. The rock consisted of a dark porphyry, with which the Convener was unacquainted.

Mr Hall, the tenant of the farm of Fasnacloich, on which Captain Bedford's boulder was situated, conducted the Convener to a spot, about a mile higher up the glen, where there were multitudes of much larger boulders of the same species of rock. The spot proved to be a mass of detritus, consisting of water-borne gravel, forming a sort of terrace abutting against the hill, which forms the north-east side of Glen Creran. This terrace is covered by numerous boulders, some of very large size. A view of one of them is given in fig. 8, Plate I.

This boulder has the Celtic name of "*Fas-na-cloich*," or "*Fas-na-clach*," which means "stone with growth,"—referring to three trees growing on it, two on the top being firs (each about 15 feet high),—one at the side, a stunted oak. The name of the farm occupied by Mr Hall, and of the residence of the proprietor, Captain Stewart, is Fasnacloich, so-called, most probably, after the boulder.

The boulder with the three trees on it is about 25 yards in girth; its length is 23 feet, its width 15, and its height, in so far as visible above ground, is 15 feet.

Another boulder, a few hundred yards to the south, measured (above ground) 18 × 18 × 12 feet.

It deserves notice that the sharpest end of each boulder points in the same direction—viz., about S.W. (magn.)—*i.e.*, towards the mouth of Loch Creran.

The terrace on which these boulders lie, is about 290 feet above the sea.

Hall mantioned that, in a higher part of Glen Creran, the boulders are more numerous, and some of them larger than the two examined.

All the boulders appeared to be of the same species of rock. Hall, who evidently had some practical knowledge of rocks, called it a black granite, and affirmed that there was no granite like it in all that district. The rocks of the mountain on the opposite, or south side, of Loch Creran, rising steeply to a height of above 2000 feet, he knew were a grey granite. The Loch Etive granite, about four miles

to the south, and the Durra granite, about eight miles to the east, being of a light grey colour, he had always wondered where these dark coloured boulders could have come from.

The rocks in Loch Creran, and in the hills immediately adjoining, are a blue schistose clay slate, with a rapid dip.

One or two other points may here be noted, communicated by Hall :—

A small river runs into Loch Creran, at its head, flowing out of a small fresh-water lake, which is separated from the sea by a spit of gravel and sand, crossing the valley, and cut through by the river. The sand, Hall stated, is full of sea-shells, and so is the bed of the lake, and even the channel of the river before reaching the lake. In this last-mentioned river, the shells are in a bed of fine clay—whitish in colour, which is used as a manure for arable land. In fact, it is this bed of shell clay which originated the name "*Crer-an*," i.e., "*Clay*," or "*Chalk River*."

These facts indicate, of course, a period when the sea stood at a higher level—to the extent of at least 20 feet, which is about the height of the shelly bed above mentioned. When the sea fell to its present level, a blockage of drift, now between the sea and the lake, caused the lake to be formed, with an overflow by the river, which runs out of the lake into the sea. There are several other places in the West Highlands where there are fresh-water lakes close to the sea, formed in like manner.

With regard to the boulders, it occurred to the Convener, judging from their locality and their position, that they had probably been floated up Loch Creran, and been then stopped in their further progress by the contraction of the valley and the higher level of the land.

But if they were floated up Loch Creran, from what quarter did they come? It was natural to look to places facing the mouth of Loch Creran, if in these places there were mountains composed of rocks similar in composition to the boulders. The island of Mull, situated to the W.S.W. of Loch Creran, seemed therefore to be one locality which might have supplied the boulders, as from Mr Judd's instructive paper on Mull,* describing numerous varieties of granite in the mountains of that island, it appeared likely that rocks of the same character as the Fasnacloich boulders existed there. With

* See "Geolog. Society's Trans."

the view of testing this idea, the Convener sent specimens of the boulders to Professor Judd, who he heard had, during the past autumn, spent three months among the Mull mountains, and asked him to state whether he recognised the rock composing these boulders as being identical with, or at all events similar to, any of the Mull rocks? Professor Judd was so obliging as to respond to the application.

With the Fasnacloich specimens, there went to Professor Judd specimens of the rock composing two very large boulders on the shore at Appin, which rock the Convener found on examination to be the same as that of the Fasnacloich boulders. These Appin boulders lie on upturned blue clay slate rocks. Their shape indicated that they had undergone great friction, in consequence probably of being rolled over the sea-bottom by icebergs floating through what was then a sea strait, but now the Linnhe Loch, and the chain of lakes forming the Caledonian Canal. Sketches of these Appin boulders were taken. The largest is 15 × 11 × 10 feet. Both boulders are well rounded at the angles.

Professor Judd's Report is in the following terms:—

"*Appin Boulders*, No. 1.—This rock is not a granite, but a rock of basic composition. It appears to be a gabbro with some black mica. It is very similar in character to the gabbro of Skye, Rum, Ardnamurchan, and Mull, which are described in my paper. I think there is no room to doubt it was derived from one of these localities—the rock is so peculiar and well characterised.

"*Fasnacloich Boulders*, Nos. 2, 3, 4, are very ordinary gabbros, such as form great mountain masses in Skye, Ardnamurchan, and Mull. These rocks are of a striking character, and differ from any which I know of on the mainland. I think it is certain, they were derived from the Western Isles."

Professor Judd, in his paper on the ancient volcanoes of Mull, Skye, and Ardnamurchan, refers to proofs that these volcanoes reached a greater height above the sea-level than any of the existing Scotch mountains, perhaps even to the height of 14,500 feet,* and that "denudation" had acted to an enormous extent in breaking up the old volcanic rocks and lowering their height. Professor Judd does not particularly specify the nature of the

* Quarterly Journal of the Geological Society for August 1874, page 259.

denuding agent which he supposed produced this effect. But if the sea with ice floating in it, at a height of say 2000 or 3000 feet above the present level, be allowed to be a denuding agent, it is easy to see how the boulders of Appin and Fasnacloich, if derived from Mull or Ardnamurchan, might have reached their present positions.

The distance of Appin and Fasnacloich from Mull and Ardnamurchan is about 30 miles. The intervening sea has in some places a depth of 100 fathoms. The island of Lismore, which is in this part of the Linnhe Loch, at one spot only reaches a height of 420 feet. A sea current flowing across Mull and Ardnamurchan, towards and through what is now known as "Glen na Albin," with mountains on each side of the Glen reaching to 2000 feet above the present sea-level, might, by floating ice, have carried boulders and lodged them in lateral valleys, such as Loch Creran.

11. *Crinan Canal.*—At the summit level, about half-way between the two extremes, there is a large accumulation of boulders, chiefly angular in shape. On the west side of the canal at the "*locks*," a body of rock stands up, whose surfaces facing the north present marks of abrasion as if caused by some body or bodies passing over from the north. On the south side of this rocky knoll, lie a number of boulders which, if they came from the north on floating ice, may have been projected over the knoll by its intercepting the ice in its farther progress through this kyle or sea channel. One of the largest of the boulders is lying with its longer axis N. and S., or parallel with the general axis of the valley at this point. These conditions would be met by the sea standing at a height of from 140 to 150 feet above the present level. On both sides of the valley here there are horizontal lines traceable at that height, as if made by the sea.

12. *Island of Islay.*—The Convener, in August 1877, paid a visit to this island, for the purpose chiefly of examining the famed raised sea beaches on the adjoining island of Jura, and also of inspecting some boulders of which notice had been sent to him.

(1.) On the farm of Lossit, about three miles south of Port Askaig, there are four or five boulders of large size. Only two were seen.

One of these, 13 × 8 × 8 feet, is a composite rock containing crystals of quartz, augite, and hornblende. The stone is extremely hard; it was with much difficulty that a small specimen

was detached. The boulder was resting on a bed of bright yellow clay, apparently a sediment of deep water. The rocks of the district are a slaty schist. On inquiry, it was surmised that rock of a similar kind existed near Kildalton, about 20 miles to the S.E. But doubt exists on this point.

The other boulder, scarcely so large as the foregoing, resembled a compact Silurian rock, containing numerous crystals of a whitish felspar.

There was nothing to indicate how or from what quarter these boulders came. Their height above the sea was about 300 feet.

(2.) On the farm of Arnahoo, about three miles north of Port Askaig, and 228 feet above the sea, a boulder stands conspicuously on the summit of a hill in a position most precarious (fig. 8, Plate III.). The rock composing the boulder is a hard porphyry, quite different from the rocks of the hill on which it rests. Its height above the sea is 228 feet, and the hill itself is about 300 yards from the sea, towards which it slopes very steeply.

The boulder is not absolutely on the highest peak of the hill, but a few feet below the peak, and on the slope which faces north by east (magn.). The only way in which the boulder could have stuck on this slope was by its coming right against it, and being let down on it gently, *i.e.*, without falling from a height. It must have come in a direction from N. by E. If floating ice brought it—and no other way is here conceivable—from the south, the boulder could not have reached its present position. It would have stuck on the south side of the hill. It could not have reached its position by a somersault over the hill top, for the impetus acquired by its fall would have projected it down the hill altogether.

As bearing on the direction from which this boulder may have come, it is proper to add that towards the north-west there is a range of hills, apparently much higher than 300 feet, whilst towards the north and north-east it is open sea, and the island of Mull is in that direction.

(3.) On the farm of Persibus (occupied by Mr Rounsfell), about three miles S.W. of Port Askaig, four or five boulders, well rounded, occur, and were seen. They are all of a hard porphyritic rock, differing from any of the Islay rocks. Their height above the sea was found to be about 228 feet.

With regard to the probable line of transport to their positions,

it may be noticed that towards N. by E. there is an opening or depressed part of the country, through which the boulders might have been floated to their sites.

Mr Rounsfell pointed out a very large boulder situated on a hill slope to the north, about two miles distant, which, however, the Convener was unable to visit. But Mr Ballingall, factor on the Islay estate, has had the kindness to examine the boulder, at the request of the Convener, and he reports as follows:—"Girth, 33½ feet; height, 11 feet; length, 12 feet; breadth, 18 feet. It lies on clay slate rocks, and is all exposed to view. Its *thickest* end faces S.W. Its height above the sea is 410 feet." Mr Ballingall has sent with his letter a small chip of the boulder. It proves to be an igneous rock, with much hornblende. It has probably come from some northern region. The weight of the boulder Mr Ballingal estimates at 25 tons.

(4.) On the south side of the high road between Bridgend and Port Helen a boulder rests at the foot of a low hill which faces about due north. The boulder is tolerably well rounded, and about 7 feet in diameter. It is a stranger to this district. Most probably it came from the north like the rest, and was in its farther progress intercepted by the hill at the base of which it lies. Its height above the sea is about 50 feet. (See fig. 10, Plate III.)

(5.) On the west coast of Islay, in the parish of Kilcheran, there are porphyritic boulders lying on the blue slate rocks, and so situated as to make it clear that they have been brought and lodged there by some agency from the N.W.

Below the old parish church of Kilcheran a small stream joins the sea through a valley in a direction W.N.W. (magn.). The rocks on the south bank of the stream are ground down and striated in such a way as to show that some force has passed obliquely across the valley from N.W.

In regard to these Islay boulders, it is very apparent that they have all come from the north—some of them very probably from Mull. It is also rather remarkable that the largest should occupy sites very nearly on the same level, viz., 228 feet above the sea, a circumstance suggesting the same means of transport. As bearing on this last point, it may be observed, that on various parts of the Scotch coasts there are traces of old sea-beaches, at heights between 250 and 500 feet above the present sea-level.

13. On the *Peninsula situated between the Firth of Clyde (on the east side), and Loch Striven (on the west side)*, there are several boulders of some interest.

(1.) At Dunoon and Kirn there are boulders of a micaceous sandstone rock, all well rounded, lying on the edges of the blue slate rocks which form the beach. One has had painted on it the words "*Jim Crow*," being $15 \times 8 \times 6$ feet; another, the words "*John Bull*," $15 \times 12 \times 6$ feet.

It was stated to the Convener by a local correspondent, that rock of the same nature as in these boulders occurs in the Holy Loch, situated about a mile to the north-west.

Two of the boulders on this part of the beach are so fixed as to indicate from what quarter they must have come into their present position, viz., from the North. Sketches of these were taken.

(2.) Along the shore towards Innellan there are numerous boulders differing from the rocks on which they lie. Some of these rocks show surfaces smoothed and striated, the striæ running north-east and south-west—a direction parallel with the general line of coast. Some local agency has, therefore, probably been at work here.

(3.) On the east shore of Loch Striven lies the large, well-rounded boulder, called "*Craig na Calleach*," or "*Stone of the Witch*"—the legend being that in former times, the witches inhabiting both banks of the loch, threw these great stones at one another. It is said that on the west bank of the loch, near Strome Point, and almost immediately opposite to "Craig na Calleach," there is a boulder of about the same size—which, however, the Convener was unable to go in search of. "Craig na Calleach" is a compact schist of a light grey colour, with thick nodules of quartz in it. The rocks of the beach on which the boulder lies are a slaty schist of a greenish blue colour. A sketch was taken.

(4.) On the farm of *Ach-na-foud*, situated about a mile from "Craig na Calleach," there is on the slope of a hill an angular boulder. It is at a height of 222 feet above the sea, and on the edge or verge of a precipitous bank. It rests partly on rock, and is in a very critical position. If the bank be now in the same condition as when the boulder was deposited, it must have been le down very gently or gradually, to avoid receiving an impetus which would have caused it to roll down the bank. A sketch was taken

BERWICKSHIRE.

In the parish of Dunse the boulder clay has lately been cut through for some hundred yards to make a new road, and to a depth of 8 or 10 feet below the surface of the boulder clay. Beds of gravel and sand lie over the boulder clay, in some places to the thickness of 12 feet. On an inspection by the Convener (November 1877), in company with Mr Stevenson, Dunse, boulders in the clay were recognised as having all come from the west, chiefly W. by N. The Kyles Hill and Dirrington Hills porphyries were among these; the former is three miles W. by N., the latter six miles W.N.W. There were also sandstones with fossils, which Mr Stevenson knew to have come from a sandstone rock a few hundred yards to the westward, and which he pointed out to the Convener. The fossils were the ordinary plants of the coal formation, and an annelid.

DUMBARTONSHIRE.

1. *Loch Lomond.*—The large mica schist boulder reported to the Committee by Mr Jack, and mentioned in the Committee's Second Report (Roy. Soc. Proc. for 1872–73, p. 152), was visited by the Convener, in company with Mr Smollett of Cameron House. Its provincial name is "*Kerstone Galloch*," it is situated on the farm of Callendoon, and is about 150 feet above the sea. Its length is 28 feet; width 19 feet; depth 12 feet.

It is shown on fig. 11, Plate III., with Mr M'Arthur, tenant of the farm, standing on it.

Originally, the boulder had been in a somewhat higher position. A small stream running past the boulder at its east side had washed away part of the gravel bed on which it had been resting,—so allowing it to sink.

With reference to the quarter from which this boulder was transported, Mr Jack suggested that if it came from the west, it must have come over hills from 1000 to 1200 feet high; and therefore he thought it more probable that it had been floated south down the valley now occupied by Loch Lomond, and then floated west up Glen Fruin.

It appeared to the Convener, that the line of transport was more likely from the westward. The land towards W. by N. (true), is on about the same level as the land to the north-east, as shown by

the contour lines on the Ordnance maps of the district. If the boulder came from the westward, there would be no obstruction to its progress in a direct line; whereas, if it came from the north end of Loch Lomond valley, as suggested by Mr Jack, it must have changed its course to reach Callendoon.

2. On a moor, about half a mile to the north east of the above boulder, there are several smaller boulders of mica schist, of the shapes and sizes shown on fig. 12, Plate III.

It will be observed that they all occupy similar positions in respect of their longer axis, and their sharpest end. Their height above the sea is about 250 feet. The rocks of this district are Old Red Sandstone. There is much probability that these boulders had been left here by floating ice, in a current flowing from the westward; and that they acquired their bearings from the action of the current.

3. On the west side of Loch Lomond there is at Arden a low valley, which runs up from the Loch in a westerly direction. The summit level of this valley towards the west is about 150 feet above the sea.

Along the south side of this valley a number of boulders, chiefly of primitive rocks, have been deposited. They are at a height of about 94 feet above the sea. As usual, the most frequent position is here, as elsewhere, N.W. and S.E. for the longer axis, and the sharpest end towards the west.

4. In the policy of Cameron House a boulder of gneiss, $6\frac{1}{2} \times 5 \times 5$ feet, is lying on gravel, and at a height of about 55 feet above the lake, or 80 feet above the sea. Its longer axis is N.W. and S.E.

5. There is a hill called "Caer-man," about 3 miles to the S.W. of the south end of Loch Lomond. Its height above the sea is 720 feet. From its top, a good view is obtained of Helensburgh and Greenock towards the S.W.

The rocks on the top of this hill are a coarse porphyry. Huge fragments have been strewed in great abundance down the side of the hill sloping eastward, and especially S.E. The unmoved rocks present their west surfaces rounded and smooth, their east surfaces angular and rough.

On examining the separate blocks where heaped upon one another, it was apparent that the uppermost blocks, to obtain their positions, must have been projected on the others from the westward.

EAST LOTHIAN.

*Linton.*—On the farm of Drylaw, a greenstone boulder, $5\frac{1}{2} \times 3\frac{1}{2} \times 3$ feet, was found in cutting a deep trench through the boulder clay. The N.W. end was the most rounded. The longer diameter was N.N.W. (magn). There were no striæ on the top, but there were horizontal striæ on the two sides fronting the N.E. and the S.W. These two sides met in an angle towards the N.W. If a current had flowed from W. by N. the current would divide at the angle; and if ice floated in the current, the striæ on the two sides might have been produced by hard pebbles from the westward pushed against them. The smoothing and striation on the north were greater than on the south side. Close to the boulder there were pebbles of limestone shale, sandstone, and coal, which most probably came from the westward. The nearest greenstone rocks are on the Garlton hills, situated about 6 miles to W. by N. The boulder, therefore, most probably came from these hills.

About half a mile to south, there are rocks (viz., in Linton village, and in a railway cutting to the west), presenting smoothings and striations, made by some agent moving over them from W. by N.

FIFE.

1. *Isle of May.*—There are small Sienitic boulders on west side, at sea-level. On the west side there are also smoothed rocks. Direction of smoothing agent has been from W. $\frac{1}{2}$ N. No boulders or smoothings are on east side.

2. *In Bogward Den* (Mr White Melville's property), 3 miles west of St Andrews, there is a boulder of conglomerate rock. Probably it came from Drum Carro Craig, which is said to be same species of rock, and situated some miles to N.W. The legend is, that the devil threw it from that hill, when the first Protestant church was being erected at St Andrews.

3. *At Kincraig, Fife,* there is on the beach a granite boulder, with girth of 23 feet and height of 4 feet. The lower half is angular, the upper half rounded. Has this boulder been floated from westward, and been stranded on the rocks at Kincraig? Stirling Castle, which is visible, bears W. $\frac{1}{2}$ N. But it probably came from a more north-westerly direction. Fragments of this

Kincraig rock (a trap tuff), have been carried eastward, and were found in the cuttings made for the railway 2 miles distant from Kincraig point.

4. *At Elie.*—Whinstone boulder on beach, 8 × 4 × 2½ feet. Its longer axis N.W. Striæ on boulder run N.W.

INVERNESS.

The Convener having been informed by the officers of the Ordnance Survey that some remarkable horizontal terraces had been discovered by them in Glendoe, a valley branching off from Glen Morriston, on the north side of the Caledonian Canal, he took the opportunity, when paying a visit to Mr Ellice of Invergarry, of going to Glendoe.

Under the guidance of two gamekeepers on the property of Mr Grant of Invermorrison, who reside at the foot of Glendoe, the Convener proceeded to the head of Glendoe, the place indicated in his map by the Ordnance Surveyors.

Unfortunately, a heavy fall of snow had (17th October 1877) occurred during the night preceding this visit, and it continued during the expedition.

There was at first some difficulty in making the gamekeepers comprehend the spot wished to be reached; and it was not till the party had gone some miles up the valley of the Doe, that the gamekeepers began to see what was sought for at the head of the glen. This was brought about by the Convener drawing attention, as he proceeded up the valley, to two lines of a terrace or flat noticed by him on a hill on the opposite side of the river. On his asking the keepers, whether there were similar lines at the head of the glen,—still about 6 miles distant, as they alleged,—the answer was, that there were such terraces, and so remarkable, that on one occasion, when accompanying a shooting party, some of the gentlemen remarked, that marks were there of Noah's flood!

The Convener was encouraged by this information, and in spite of snow and wind continued his progress up the glen.

The keepers stated that the marks to which they referred were on "English Hill;" and that though this hill was rocky on some parts, there was a great deal of sand and gravel near the top.

Following up the river Doe, a point was reached where the river

divided into two branches, and called by a Celtic word meaning "Tongue of the Burus." The portion of the stream towards the right has the name of "Carriscreuch," or "Middle Corry;" and it was along that stream, flowing through what the keepers called "The Long Glen," that "English Hill" could best be reached. But the snow was here so deep, that no track was visible, and walking became dangerous, at least to a stranger.

At this point a consultation was held. The height above the sea reached was only about 850 feet, whereas the highest terrace marked by the Ordnance Surveyors was 1280 feet, and apparently still about 2 miles further up the glen.

The gamekeepers' advice was to abandon any hope of reaching the terrace, and to be satisfied with a distant view of the place, which could be obtained from a low hill in front.

This low hill accordingly was ascended, and with satisfactory results. The hill itself was found to consist, as shown by numerous scaurs, of fine gravel and sand; and on its flat top, the aneroid showed a height above the sea of 1190 feet.

This gravel knoll was as it were in an amphitheatre of hills, on several of which, towards the west, horizontal terraces were observed, at a somewhat lower level. These appeared to run continuously for about a mile. On the opposite side, the hill bearing about east showed a short line at the same level. Looking towards "English Hill" on the N.E. no terraces were discernible; the snow, owing to the direction of the wind (which was west), was so thick on the slope of the hill facing the knoll, that inequalities, if any existed, were undiscoverable. But one of the keepers pointed in the direction of the part of the hill for the terraces he had before spoken of. The part so pointed out seemed to be about 2 miles distant, and at an elevation of about 100 feet above the knoll on which the party were then standing.

The Ordnance Surveyors had marked on the Convener's map two lines of terrace, one at 1280 and the other at 1140, as existing on a hill on the left side of the Doe water. Though, from the circumtances above stated, it was impossible to make out these terraces, there was enough discovered to show a line at the lowest of these levels on the other hills adjoining—and the existence of detritus quite capable of being formed into a terrace at a much higher level.

One of the keepers stated that on a hill towards the N.W. there were beds of gravel and sand to the very top, and without any covering of turf. He pointed in the direction of Ben Doe, which has an elevation of 2000 feet above the sea.

The Convener having on his way up Glen Doe observed several large boulders on the slope of a hill above him on the left hand, resolved to visit them on his way back. So, accompanied by one of the keepers, he ascended the hill, and in looking across the valley, he discovered four horizontal terraces on the opposite hill, and continuous for about half a mile. They were apparently on detritus, for at one spot, where a rock projected, there was an interruption.

The uppermost terrace the aneroid showed to be about 985 feet above the sea, the lowest about 895.

The first of the boulders visited was 919 feet above the sea. Its dimensions, roughly measured, were $14\frac{1}{2} \times 11\frac{1}{2} \times 7$ feet. It was a coarse reddish granite, and very angular. It could not have been rolled or pushed. It seemed to have been carried from its parent rock, wherever that was, without undergoing any change of form. It was resting on gravel and sand.

The next boulder reached was at a height of 1204 feet above the sea. It also was a coarse red granite. It was about 30 yards in girth, and 14 or 15 feet in height. It is known as "The Glen Morrison Stone," probably because of being the largest boulder in the glen.

This boulder is on a flat, and in looking across the valley, a terrace is seen which corresponds in level with the boulder.

In several parts of the hill the boulders were in clusters or groups, piled over one another.

It deserves notice that all these boulders were resting on gravel and sand; and that the hills on both sides of the valley were thickly covered with detritus.

The gamekeepers spoke of a very large boulder at Clachnaharry, about 16 feet high, on the south side of Loch Clunie, which is two or three miles to the west of Glen Doe. The Convener saw it through his glass.

It may be added here, that Mr Ellice of Invergarry informed the Convener of a large bed of pure white sand, which he could not distinguish from sea sand, existing on a property belonging to him in that district, at a height of about 1000 feet above the sea.

1. In September 1877 the Convener visited excavations on the *north side of Craiglockhart Hill*, about two miles S.W. of Edinburgh. His attention was drawn to them by Mr Hutchison of Carlowrie.

These excavations were in the boulder clay. A number of boulders had been exposed, and were still undisturbed in their original positions.

The largest was angular, the smaller boulders were comparatively round. The greatest number were of blue whinstone rock. Among the smaller boulders, there were some of sandstone. The contractor for a large new building about to be erected being present, had his attention drawn to the sandstone boulders, and was asked if he knew any rock of the same kind which was in sufficient quantity to be quarried? He said that the sandstone of Hailes Quarry and Redhall Quarry was the same rock as that of the boulders. On being asked to point out the direction of these quarries from where the boulder lay, he pointed in a direction which was N.W. (by compass).*

The height of these boulders above the sea is about 340 feet.

2. At *Granton Harbour* (on west side) a very large blue whinstone boulder lies on the beach at high-water mark, part of which only is visible, the rest being covered and concealed by the sea wall which protects the road. On the upper surface of this boulder, there are innumerable striæ, the direction of which is W. 3° S. (magn.).

About 100 yards to the eastward, there is another whinstone boulder having an iron ring in it, by which boats or vessels may be moored. There are striæ on it running in the same direction.

Between these two boulders there are some strata of hard sandstone rock, portions of which have been ground down and show striations running also as above.

3. In the *New Docks, situated to the eastward of Leith*, there is an immense bed of boulder clay, which continues along the coast eastwards for some miles.

This boulder clay at the Docks is covered by a muddy sand in

* These quarries are about a mile distant from the site of the boulders.

horizontal beds about 8 or 10 feet thick. On the surface of the boulder clay there is a bed of oyster shells, of large size. There is as usual on the surface of the boulder clay a great accumulation of boulders, these having remained when the upper portion of the boulder clay bed was washed away by the sea. Most of the boulders are well rounded. The largest I saw, a light-coloured blue whinstone, measured $10 \times 8 \times 6$ feet, and was estimated to weigh 18 tons. About nine-tenths of the boulders are whinstones, but there are also some of quartz, limestone, sandstone, silurian, granite, and black ironstone concretions from beds of shale. These boulders have evidently come from the westward. On a great many, there are ruts or striæ all maintaining the same direction, viz., W. by N. (magn.). Those which are longer than they are broad, have their longer axis in the same direction.

Among the boulders, there were two metallic in composition, which deserve special notice.*

One, nearly spherical, measures $7\frac{1}{2}$ inches in circumference, and weighs 24 oz. It was found about $4\frac{1}{2}$ feet down in the boulder clay, among the large boulders.

The other ball was even more spherical, its least girth being 30 inches, and its greatest 31 inches. Its weight was 54 lbs. It was found 10 feet below the top of the boulder clay.

Professor Crum Brown (Edinburgh University) was so obliging as to examine both of these balls for specific gravity and composition. He reports that the smallest ball is marcasite or white iron pyrites, and that its specific gravity is 4·63. It is entirely of pure ore, being apparently unmixed with any other substance.

With regard to the larger ball, the Professor has sent the following report:—

"The fragment of the large round stone which I took for examination had a specific gravity of 3·36. It consisted of a mixture of silica (not obviously crystalline) and iron pyrites, in the following proportions:—

"Silica, 52·3<br>"Pyrites, 47·7 } per cent.

* The Committee have to thank Mr Hugh Campbell, who is professionally engaged in the formation of these new docks, for bringing to them the two remarkable balls here referred to, as well as for affording to the Convener opportunities for seeing the excavations.

"Calculating from these numbers and the sp. gr., it is plain that the pyrites must be in the 'marcasite' form, as 'pyrite' would give a considerably higher sp. gr.

"The sp. gr. of the whole stone, *i.e.*, the mean sp. gr., was found to be 3·28. It cannot, therefore, be a uniform mixture."

Mr Murray having kindly offered to examine, microscopically, this large stone ball, has sent the following report :—

"*Challenger Office, Teviot Row, May* 1878.

"Dear Sir,—The microscopic section of the boulder is made up of crystalline particles of quartz and marcasite. The marcasite fills the interstices between the grains of quartz; and among the quartz there are pieces of mica. (Signed) John Murray."

The Convener paid two visits to the excavations in the boulder clay at Leith to examine the spot where these two remarkable balls were found. He saw the superintendent, who was directing the excavations, and also the "*navvy*" who found the larger ball. The latter pointed to a whinstone boulder, and said the "big bullet" was close to this boulder.

There can be no doubt that both balls had come with the boulders, and had been deposited with them in the great bed of clay which covers the rocks in this district. This bed extends for fully half a mile on each side of the Water of Leith at its mouth, and reaches to a depth in some places of nearly 100 feet.

The black ironstone concretions found in this boulder clay bed show marks of friction. There are strata of shale containing such concretions, two or three miles to the westward. These concretions, as well as the boulders of granite and quartz, clearly indicate transport on a large scale from the westward.

The Convener learns from Mr Robertson, C.E., Albany Street, Edinburgh (who planned both the Albert Docks at Leith, executed some years ago, and the new docks now being constructed), that similar metallic balls were found in the Albert Docks excavations. But he has no specimens of them.*

* Since the foregoing was written, the Convener has received from Mr Charles W. Peach, of 30 Haddington Place, Edinburgh, a letter regarding marcasite nodules, from which letter, with Mr Peach's permission, the following extracts are made :—

4. At *Alnwick Hill, near Liberton Church*, at an elevation of about 350 feet above the sea, extensive excavations have been made in the boulder clay for the new Edinburgh water-works. The boulders consist chiefly of fragments of rocks, which are known to be *in situ* situated in districts of the country to the west and north-west. The great majority of the boulders are of hard red sandstone rock, such as occurs at Grange and Merchiston, to the west of Edinburgh, though these places are at a lower level. There are boulders of marine limestone, similar to rocks of that description in Linlithgowshire. There is an immense quantity of blue-coloured greenstones and dark-coloured basalts, and also buff-coloured felspathic rocks. There are some small boulders of pure quartz, which probably hail from the Silurian rocks to the north-west of Callendar and Doune.

"In the Falkirk and Slamannan district a band of these nodules, known as '*Speckled Ball Ironstones*,' occurs. It occupies a horizon a few fathoms above that of the '*Slaty Band Ironstone*,' the base of the Coal measures.

"The direction of the *striæ* on the rocks and the carry of the boulders and boulder clay is towards the east, and varies from E. 10° N. to E. 15° N.

"Near Kilsyth, and about 2 miles to the west of that place, the tributaries of the Corrie burn cross an area of blue shales, with several courses of ironstone nodules. Some of these are of iron pyrites (marcasite), and are known among the mining population as '*brassy balls*.' They occupy a horizon between the Hosie and Hurlet limestones, near the base of the carboniferous limestone series.

"The direction of the *striæ* and carry of the boulders in this district is E. or E. 5° N.

"Either of these sources could supply *balls* at Leith, as they are right in the direction of the ice-flow.

"As to *concretionary balls in sandstone*,—there is on the coast of East Lothian near Cockburnspath, to the north of Cove, a cliff of calciferous sandstone full of spheroidal concretions, which weather out on the wasting of the cliff by the sea, and being harder than the matrix, they lie piled up in great numbers at the base of the cliff. Many of them are of very large size.

"Similar concretionary balls occur in sandstone rocks at Grange Quarry, near Burntisland, from whence, no doubt, the ball found lately at Leith was carried. (Signed) "C. W. Peach."

This information in regard to marcasite brassy balls, the Committee deems highly interesting. If the marcasite ball found in the boulder clay at Leith, was transported from any part of the district situated to the north of Glasgow, as suggested by Mr Peach, what was the transporting agent to suit those localities? A glacier moving from west to east by the action of gravity would be hardly conceivable. The levels preclude that agent. A sea current, loaded with floating ice, seems a more probable conjecture.

Many of the boulders occupy positions, present shapes, and bear marks of some interest.

The largest seen by the Convener were about 7 feet long by 4 feet wide, and 2½ thick or deep.

The boulders were all well rounded and smooth, but more particularly so on what had been the upper and the under sides.

Mr Black, the superintendent of the excavations, being aware of the interest attaching to the position of the boulders and the *striæ* on them, had, with a compass, ascertained that the long-shaped boulders, before being moved, generally were lying in directions varying between W.N.W. and N.W.; that the striæ, when such existed, were almost always parallel with the longer axis of the boulder; and that there were striæ, sometimes only on the upper side, sometimes only on the lower side, sometimes on both sides. In one of the boulders, well rutted on the under side, he had remarked that the ruts were deepest at the east end of the boulder, and that they gradually diminished in depth and numbers towards the west. This feature might be accounted for on the supposition that the boulder, whilst being pushed forward, encountered hard obstacles which produced deep ruts on the boulder when the first contact took place, afterwards the boulder would rise over these obstacles, and in consequence the striæ produced by them would diminish in depth.

5. *Tynecastle, near Edinburgh.*—A basalt boulder, 4½ × 4 × 2 feet, was discovered, striated on both upper and under side, but the ruts were much deeper on the under side. The under side ruts had begun to be formed at the east end of boulder,—the striæ on the upper side begun at the west end. This might be accounted for by supposing that the boulder had been pushed towards the east over hard rocks, and that floating ice from the westward had pushed stones over the upper surface. The smallest end of boulder pointed towards west. The sides of the boulder were well rounded.

This boulder lay in a hill of muddy sand containing many pebbles of all kinds, hard and soft, such as quartz, shale, and coal. Height above sea, 200 feet.—*Ed. Geol. Soc. Tr.*, vol. ii. p. 347.

PEEBLESSHIRE.

At the east end of the town of Peebles there is a boulder of white quartz, about 3 feet long, $2\frac{1}{2}$ feet broad, and with a girth of about 7 feet. It is now built into a wall. Previously to its being thus disposed of, the stone stood from time immemorial in an adjoining low hill, which in consequence had obtained the popular name of the "White Stone Knowe." It is alluded to as a boundary stone in a title deed dated in 1436. Mr Richardson, the Secretary of the Edinburgh Geological Society, who was the first to take public notice of this boulder, says that "the nearest beds of quartz are about 80 miles to the N.W." The boulder on its surface is smoothed and polished. It is, like many other boulders, rudely pointed at one end, whilst the other extremity is more broad and heavy. The height above the sea is 550 feet.—*Ed. Geol. Soc. Trans.*, vol. ii. p. 397.

PERTHSHIRE.

1. *Loch Tay.*—On the farm of Morenish, situated on the north bank of the lake, and about 2 miles from the village of Killin, there are several boulders worthy of notice.

Figs. 13, 14, 15, Plate II., are intended to show the positions and specialties of these boulders. They were at a height of about 1400 feet above the sea, assuming Loch Tay to be 300 feet.

These boulders had all come from the westward, viz., down the valley, as shown by the way in which they were fixed.

If the question be, whether they were brought by glacier or by floating ice, the answer is, that there is not much evidence either way. It may however be remarked, that if they were pushed forward by a heavy glacier, it is odd that the boulders should not have been carried further down the valley, and that the obstructions on their east side, against which they have stuck, should not have yielded under the pressure of a ponderous glacier. The boulders in figs. 13 and 14 were resting on detritus, and pressing against detritus only on their east sides. The boulders in fig. 15 was pressing against a hard rocky stratum of clay slate on its east side.

In several parts of the hill, smoothed rocks of mica schist occur, with knobs of quartz standing up above the general surface. Being

harder than the mass of rock, they had resisted the friction better; these knobs were smoothed, the smooth parts being always on the west sides.

Fig. 16, Plate III., shows a rock with joints. The projecting angles facing the west have been smoothed by some abrading and grinding force.

2. *Glen Dochart.*—There are many boulders of considerable size, resting on detritus, and chiefly on the south side of the valley.

One near an old toll-bar measured, in so far as above the ground, $13 \times 12 \times 8$ feet, at a height of 630 feet above the sea.

At the small farm-house of Wester Lix, at a height of 660 feet above the sea, there is a flat or terrace, partly rock, partly detritus, on which there are several large well-rounded boulders, two of them a coarse granite, probably from Ben Cruachan.

On ascending the hill towards the south, a boulder, $12 \times 9 \times 5$ feet, was met with, at a height of 1116 feet above the sea. Its longer axis bore E. $\frac{1}{2}$ S., which is also the direction of the axis of the valley in this place. There being no rocky hill near, from which this boulder could have come, it has certainly been brought to the spot where it now lies by some transporting agent.

At the height of 1250 feet there is a mass of rock on the same side of the valley, and nearer the top of the ridge, which has on it some noteworthy marks. The rock stands out prominently, and forms a nearly vertical cliff, as shown in fig. 17, Plate III. On the side facing the west, there are horizontal groovings, apparently formed by some force, which, acting on the whole mass, has worn down certain portions more than others, these portions being less compact, and so more capable of abrasion.

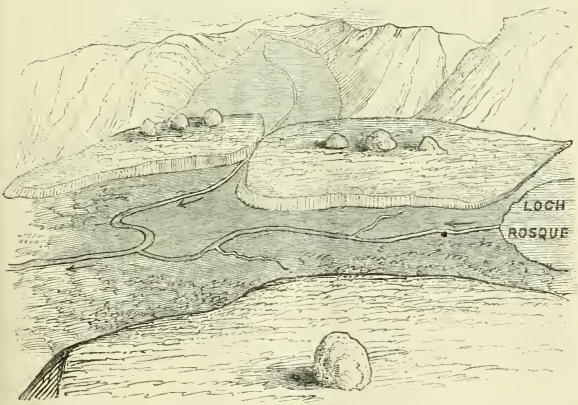
Such abrasion might have been effected by a body of water passing from the westward; and more readily, than by the solid ice of a great glacier.

On the top of the ridge forming the south bank of this valley (Glen Dochart), a cairn stands at a height of 1500 feet above the sea. A boulder of considerable size lies on the top of this ridge, on the east side of a projecting knoll. Has the boulder been stranded on what was the lee side of the knoll?

At *Auchnasheen* (Dingwall and Strome Ferry Railway,) there is a boulder about 15 feet in girth, which stands on a flat of detritus about 610 feet above the sea.

In this district, there are several other detrital flats, in sight of this one, all nearly on the same level. There can be no doubt that these flats have been originally one continuous plateau, which formed a sea-bottom. It has been cut through by several streams, the banks of which, about 18 feet high, show an enormous accumulation of gravel and sand;—sand, *below* (deposited probably when the water was deep); gravel, *above* (deposited when the water was shallower and more subject to currents).

The annexed diagram represents a portion of these remarkable flats,—cut through by several streams, the principal of which flows from Loch Rosque,—situated to the north of the boulder. The knobs




on the woodcut are intended to represent knolls of gravel or sand—remnants of a greater mass of these materials. The boulder is well rounded, and it has evidently come from a distant quarter.

Professor Nicol of Aberdeen has expressed an opinion * that the formation of these Auchnasheen terraces is due to the action of a

* Nicol's Geology of Scotland, p. 69.

great river flowing from the west. I regret to differ on this point from a geological friend; but I can see no grounds for that opinion.

To the east of Auchnasheen, close to the railway, there are several spots of rock evidently rounded by friction—whether by ice or by water, or by both, it is difficult to say. Their height above the sea is about 780 feet. On the hills, on each side of the railway, there are traces of horizontal lines on the detritus, which deserve better observation than could be given from the railway carriage.

STIRLINGSHIRE.

1. *On Sheriffmuir*, 3 miles from Bridge of Allan, near Blackford, there is said to be a large boulder, called Wallace's Putting Stone.

NORTHUMBERLAND.

It was intended that only Scotch boulders should be inquired after by the Committee; but it is not irrelevant to notice a boulder which, though now in England, was probably transported from a Scotch mountain.

In Chillingham Park, the seat of the Earl of Tankerville, near Alnwick, there are several small boulders of granite. The rocks of the immediate neighbourhood are carboniferous sandstones and limestones. The nearest point for granite is the "Big Cheviot," eight miles to the W.N.W., and reaching a height of about 1800 feet above the sea. The largest boulder is 3 feet 2 in length, 2 feet 4 in width, and 2 feet high. It is round in shape, and about 400 feet above the sea.

Several valleys and ridges of hills lie between Chillingham and the Big Cheviot, across which the boulder must have been transported to reach its present site.

Remarks by David Milne Home, LL.D., Convener of the Society's Boulder Committee, on presenting the Committee's Fourth Report at a Meeting of the Society, 20th May 1878.

1. In presenting a Fourth Report from the Society's Committee on Boulders, I may be allowed, first, to refer to the main object for which the Committee was appointed.

It was to collect data which might help towards a solution of the problem, by what agency boulders in Scotland had been transported from the parent rocks to the positions they now occupy.

The Transactions of the Society contain numerous papers by eminent geologists on this question.

At a very early period, Sir James Hall, when he drew attention to many large boulders, and also to the remarkable appearances called "crag and tail" in the midland districts of Scotland, ascribed both sets of phenomena to the agency of great bodies of water, which had passed over the country from west to east.

At a later period (about the year 1842), Agassiz and Dr Buckland started the idea, that as in Switzerland, glaciers had been the means of carrying masses of rock from the Alps across the valley of Geneva to the Jura mountains, so there might in former days have been glaciers in Scotland producing similar effects.

More recently a third theory was started,—that if the sea stood several hundred feet above its present level, floating ice might have been the means of transporting the boulders, and carrying them great distances.

2. There being thus three different theories of transport, each supported by eminent geologists, the Committee has endeavoured to gather facts to ascertain which theory is the most probable, or whether any better can be suggested.

I do not presume to say that the information contained in this and the previous Reports will yet allow the problem to be solved. But at all events it may be conceded that some new facts have been ascertained, which throw considerable light on the question.

I venture to indicate what appear to me to be several conclusions warranted, though in doing so I offer only my own opinion. Perhaps the Committee, after more information has

been obtained, may be induced to consider whether they will pronounce on the various questions of interest which the subject presents.

I confine myself this evening to only a few points, and chiefly to illustrate what occurs in our last Report.

3. The boulders referred to in the Report may be divided into two classes.

*First*, There are boulders which, from the nature of the rock composing them, are so soft and friable, that they could have been transported only short distances—such as sandstone, coal, and shale. In the Report, examples are given of such boulders, from Berwickshire and Mid-Lothian.

The *second* class of boulders, namely, such as are ascertained to have come from remote quarters, are composed of rocks, hard, compact, and homogeneous in composition; such as basalt, greenstone, granite, felspar, quartz, greywacke, and old conglomerate.

Boulders of these rocks have been found even as far as 80 or 100 miles from the parent rocks; and, generally speaking, they are well rounded, presenting evidence of enormous friction undergone whilst *in transitu;* and even in some cases acquiring almost a spherical shape.

Specimens of small spherical boulders are now on the Society's table.

There are, however, exceptions to the rule that boulders of hard compact rocks are generally well rounded. Cases of boulders of these hard rocks occur extremely angular in shape. Examples are shown in this Report, by the lithographs appended to it, and in previous Reports. These *angular* boulders are almost invariably at *high* levels, on the sides of mountains or near their tops. The *well-rounded boulders* are generally at *low* levels, and most frequently imbedded in boulder clay.

4. It will be asked, whether the Committee has in any case ascertained the parent rock from which a boulder has come.

The answer is, that the Committee can in no case point out the particular rock from which a boulder had originally been broken off. All they can affirm is, that in several cases they have ascertained the *district* or *quarter* from which the boulder must have come.

(1.) For example, in Berwickshire, as will be seen from this last

Report and the second Report, particular hills are specified from which boulders must have come. The direction in which they came, and the number of miles traversed, are therefore in these cases matter of certainty. In every case over the whole county of Berwick, from its lowest to its highest level, the direction of transport is from points between W. and N.W. (magn.)

The same is the case in Mid-Lothian. The sandstone boulders at Craiglockhart are shown to have most probably come from rocks situated a few miles to the N.W. The quartz and other hard rock boulders at the same place, as also at Liberton and at Leith, in like manner probably came from points between W. and N.W.

(2.) The two remarkable spherical balls of marcasite, found in the boulder clay at Leith and mentioned in this Report, must in like manner have come from the westward. A presumption to that effect arises, from the mere fact that they are in the same bed of clay which contains granite and other Highland rocks. But there is more than presumption. Mr Peach having indicated where pyrites balls might be found *in situ*, viz., at Campsie and Kilsyth, I went to Campsie last week, and on inquiry was shown some thin strata of coal, abounding in nodules of pyrites, several of the nodules so large as to weigh half a cwt. The coal is worked for burning limestone. It is too full of sulphur for domestic use. Specimens of this coal, with the pyrites nodules which I obtained on the spot, are now on the table of the Society.

Kilsyth I did not visit, because the overseer at Campsie told me that he had worked at Kilsyth, and that there were pyrites nodules in the coal strata there, similar to those at Campsie, but of rather smaller size.

Some of the nodules which I obtained at Campsie I submitted to Professor Crum Brown, that he might examine them to see whether they contained "marcasite." He has reported to me as follows:—

"These nodules have a specific gravity of 4·12, and consist of iron, sulphur, and coaly matter in the following proportions:—

| | |
|---|---|
| "Iron, . . . | 44·56 per cent. |
| "Sulphur, . . . | 52·14 ,, |
| "Coaly matter, . . | 3·30 ,, |

Deducting the coaly matter, the iron and sulphur would be in

the proportions in which they are generally found in 'marcasite,' viz.,

"Iron, 45·61; and Sulphur, 54·29."

As regards chemical compositions, therefore, the small metallic boulder may be considered as exactly agreeing with the nodules found in the Campsie coal strata. This agreement in composition affords a strong ground for inferring that the boulder had been transported from Campsie, or from Kilsyth, as suggested by Mr Peach.

With regard to the larger spherical ball found in the same bed of boulder clay at Leith, I am now able also to indicate the part of the country from which it was probably transported. Mr Hutchison of Carlowrie, happening to see this stone ball, informed me of two quarries in Linlithgowshire where concretions resembling it were in abundance. These quarries are near Humbie and Dalmeny, situated from nine to ten miles due west from Edinburgh. Mr Hutchison having sent to me several of these concretions, I was induced to visit Dalmeny Quarry. I found in the sandstone rock there, numerous concretions of all sizes up to nearly 4 feet in diameter. Humbie Quarry I did not visit, as the working of it had been given up, and it was full of water. A concretion from this last mentioned quarry, sent to me by Mr Hutchison, Professor Crum Brown has examined, with the following result:—"It weighs $17\frac{1}{4}$ lbs. It consists externally of a thin shell of sandstone, and internally of a mixture of quartz and marcasite, closely resembling the substance of the large ball from Leith. The mean specific gravity of the ball was 3·49."

There is thus a sufficient similarity of composition in regard to the stone ball and the Humbie concretions, to make it exceedingly probable that these Humbie sandstone rocks supplied the stone ball. I do not say that Humbie Quarry was the exact spot from which the stone ball found at Leith actually came. The sandstone strata which occur at Humbie and Dalmeny of course crop out elsewhere in the district near South Queensferry; all that can be said is, that the stone ball may have come, and most probably came, from some part of that district. Mr Peach mentions in his letters, quoted in the Report of the Committee, that similar concretionary balls occur in sandstone rocks near Burntisland, and suggests that the ball in

question came from that quarter. In that case, the direction of transport would be from about due N. If the stone came from near South Queensferry, the direction would be from W.N.W., which last would be more in accordance with the evidence of direction indicated by many other data.

Assuming, then, as most probable, that the large stone ball, as well as the small metallic ball found in the Leith boulder clay, came from parent rocks, situated to the westward, the next question will be, by what agency were they transported?

Mr Peach, in his letter, apparently assumes, as matter of course, that these balls were transported by the agency of *ice*. But "ice" in what form?—land-ice, or sea-ice?

If the metallic boulder came from Campsie, the distance over which it travelled to Leith could not have been less than 30 miles; and as the Campsie coal strata are only about 150 feet above the present sea-level, there would not be gradient sufficient for a *glacier* either to carry on its surface, or to push before it, debris of rocks from Campsie to Leith. Moreover, Leith is not at or near the mouth of any valley which could create or guide a glacier from the west of Scotland.

But there are in the Campsie and Kilsyth districts marks of various kinds, indicating the action of a deep-sea current. These marks it is proper to notice, as having an important bearing on the general question of boulder transport.

Mr John Young of Glasgow, in the year 1868, wrote an instructive paper in the "Transactions of the Glasgow Geological Society," on the geology of Campsie. He says (page 14)—"There are few localities in the central district of Scotland, where such an extent of polished and striated rock surface is to be seen, as along the flat summits of the south hill of Campsie. The striæ vary in their direction from a few points north of west to south of west, according to the deflection of the ground;—many tracts of the sandstone rock, still showing the channelled markings in great perfection," at about 600 feet above the sea.

Mr Young then refers to the Strathblane Valley, which lies between the north and south hills of Campsie, and to the appearances indicating that it had been "*swept by powerful currents of water*, which have helped to produce those inequalities of surface seen

along the outer margin of the tracts now occupied by the rivers Kelvin and Glazert. It was during the period when Scotland sat several hundred feet lower in the sea than it does at present, and when *the valley of the Kelvin existed as a deep sound connecting the German and Atlantic Oceans*, that those great beds of stratified sand and gravel were deposited which we now see filling up the Strath (as near the village of Torrance) to more than 100 feet above the level of the river. At other points along its course, similar deposits exist to more than 100 feet *below* the present sea-level. This shows that a *very deep sound or valley must have originally extended across Scotland, previous to the glacial period, in this particular direction.* A depression of the land to the extent of 350 feet would produce the following results :—The German and Atlantic Oceans would be united by the valley of the Kelvin, also by the valley of the Leven, Loch Lomond, and onwards by the low ground near Kippen to the Forth at Stirling. *A narrow sound through the Campsie valley* would connect the two seas, as the water-shed at Ballagan Bridge is only 330 feet. *The Campsie and Kilpatrick hills would then form two islands*, and the valleys of the Carron and the Endrick would be estuaries or arms of the sea. It is only by assuming conditions such as these, that we can hope to explain the superficial sedimentary deposits" (page 16).

In the year 1871, in company with Mr Young, I had an opportunity of visiting the Campsie district, and from my note-book I make the following extracts :—

*a.* On Craigend moor, at about 450 feet above the sea, situated two miles west of Strathblane, I found the sandstone rock presenting extensive sheets of smoothed horizontal surface, evidently ground down by friction, and presenting occasional striæ, running in a direction S.E. by S. The rock had in some places imbedded in it quartz pebbles, standing up above the general surface. Being harder than the sandstone rock, these pebbles had been able to withstand the friction ; but some of them showed marks of rubbing on their north west sides.

*b.* At this place, looking towards the N.W.—viz., in the direction of Loch Lomond—an opening between the hills, which are apparently about 1000 feet high, was discernible ; this opening being about 1½ mile wide.

*c.* At four other places on Craigend moor, from 500 to 600 feet above the sea, two to three miles apart, there were striations on the rocks, pointing repectively S.E. by S., S.E. ½ S., S.E. by S., and S.S.E.

At all these places the direction was seen to pass through the opening between the hills above referred to, indicating that the agent, whatever it was, which produced the striations might have come, and probably came, by that opening.

*d.* On this same moor (forming an extensive plateau of about 6 miles long by about 3 miles wide) I had pointed out to me by Mr Young several boulders in different places.

Two were of trap, from the Kilpatrick hills, situated some miles to the W.N.W., and at a height of 570 feet above the sea. In circumference, each boulder measured 27 feet, and, so far as not buried in the drift on which they were lying, the height of one was 4½ feet, of the other 6 feet.

Another boulder, well rounded, 500 feet above the sea, was of grey granite, weighing about 2 cwt., which Mr Young considered, from the size of its felspar crystals, to have come from Ben Awe, a mountain situated to the N.W., and distant about 50 miles.

There were several smaller boulders of old conglomerate — transported, no doubt, from the well-known band of that rock which, running from Dumbarton, crosses Loch Lomond in a N.E. direction towards Aberfoyle.

*e.* In the valley of the Blane there are deep beds of sand formed, most probably, whilst the sea occupied the valley, and numerous well-rounded boulders of all descriptions. At Strathblane Railway Station there was a deep cutting of a sandbank, with several boulders in the sand, and one in such a position as to indicate that it had fallen from some raft which had been conveying it, as it was sticking with its narrowest point downmost.*

*f.* It was remarked to me by Mr Young, that whilst boulders, gravel, and beds of sand are abundant in the valleys of Strathblane and Campsie, he had never found any marks of grinding or striation on the rocks in these valleys. These effects seemed to have been produced at levels higher than 400 feet above the sea.

* See a diagram of this sandbank and boulder in a little book, published by Edmonston & Douglas in 1871, called "Estuary of the Forth."

On another occasion, when geologising on the Campsie hills, above Glorat, situated 3 miles to the east of Campsie, and at a height of 800 feet above the sea, I found the sandstone rock striated, in a direction due E. and W. On the Kilsyth hills, a few miles still farther east, and at a height of 1200 feet above the sea, the striations on the rocks were seen to be E. and W.

*g.* One other fact observed was the immense accumulation of boulders of all kinds at Croyhill, a knoll of trap, at the summit level between the firths of Clyde and Forth—viz., about 160 feet above sea-level. As some of these boulders were of "*old conglomerate*," they afford additional evidence of an agency which brought them from the westward.*

*h.* In addition to these facts, notice may be taken of two boulders reported to the Committee by Mr Jack of the Geological Survey. One is of mica slate, weighing about 6 tons, on the Kilsyth hills, at 1260 feet above the sea, the parent rock of which Mr Jack supposes to be situated about 15 miles to the north. The other is of conglomerate, weighing about 7 tons, on the north hill of Campsie, at 1803 feet above the sea, with its longer axis W. 20° N. Its parent rock is supposed by Mr Jack to be to N.W. (First Report of Committee, p. 51.)

Now what do all these facts prove? They prove that an agent of some kind or other moved over this district, having a depth of at least 1800 feet, and covering a great breadth of country; and that, whilst this agent was moving, the rocks over which it passed were ground down and rutted and striated; large boulders, at a high level, were carried forward, and boulders at a low level were pushed in a similar direction.

There is an additional fact deserving notice. The valley at Lennoxtown, where the pyrites coal strata are worked, seems to have at one time been filled up by these strata. These strata now, however, exist only on each side of the valley. Some agent has scooped them away, whereby the present valley was excavated; and it is possible that the balls found in the Leith boulder clay form a portion of the debris of these pyrites strata so broken up.

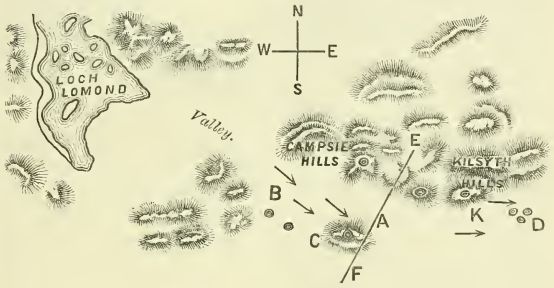
What agent can fit into all these conditions so well, as a sea current loaded with ice?

* "Estuary of the Forth," p. 95.

On this theory, it is intelligible why the rocks along the moors of Craigend and Craigmaddie, stretching for 5 or 6 miles in a direction S.E. and S.S.E., at a level of from 500 to 700 feet above the sea, should show more effects of grinding and striation than the rocks at a lower level. Had a glacier been the agent, the grinding would have been chiefly at the lowest, not at the highest levels.

The subjoined plan and section of Campsie hills and valley will make the foregoing explanations more intelligible. The plan is copied from a published map by Johnston. The section has been

Ground Plan of Campsie Valley.




A, Pyrites coal strata, out-crop of.
B, Craigend Moor, 450 feet.
C, Craigmaddie Moor, 700 feet.
D, Boulder and striated rocks at Croyhill.
K, Kilsyth coal strata.

Boulders shown by black dotts.
Striæ on rocks by arrows.
FAE, Line of section across Campsie Valley.

kindly drawn for me by Mr John Young of Glasgow, who is thoroughly well acquainted with the geology of the district. In his letter sending the section, Mr Young says—"The Campsie coal and limestone is at present worked on the flank of the north hill, as well as in the mine which you saw in the south hill. The valley between these hills is one of denudation. Several hundred feet of strata, belonging to the Lower Carboniferous Limestone series, have been removed, or scooped out by currents of the ocean.

"If you examine Sheet 8 of the horizontal section of the

Geological Survey (by Professor Geikie) you will find on the south hill of Campsie the outcrop of the coal and limestone. This sheet shows, quite as distinctly as my sketch, the valley running between the south and north hills, and the great denudation of the coal strata containing the marcasite balls."


Section across Campsie Valley ; coal and limestone strata overlaid by gravel and earth.

These explanations go far to show how the small marcasite ball found in the Leith boulder clay probably came from Campsie. A geological study of that district indicates the agency of deep-sea currents loaded with ice, which flowed upon the Campsie hills from the W.N.W., scooping out the valley which now occurs there, and breaking up to a large extent the coal strata in that valley. The debris of these strata would be swept along to the eastward; and some of the nodules forming part of these strata would be buried in the boulder clay now existing at Leith.

4. The cases which I have just been describing are of boulders, large and small, which have come from remote places, now separated by an intervening tract of *dry land* from the present sites of these boulders.

(1.) But there are cases of boulders which to reach their present sites must have crossed *arms of the sea*, even now of considerable depth and extent. In such cases, the theory of local glaciers is, of course, scarcely conceivable.

Thus on the Island of Islay, the Committee's last Report refers to several large boulders of rock, differing from any rock known in the island. At least, such was the opinion I formed after a week's ramble, and after inquiring among intelligent persons well acquainted with the rocks of the island.

So also in the Island of Kerrera, opposite to Oban, there are

numerous blocks of grey granite, though no rocks of any kind of granite occur in the island.

On the small island of Staffa, consisting entirely of basalt and greenstone, I found boulders of red granite and gneiss, which probably came from the Mull mountains, situated to the N.E. (Committee's 2d Rep., p. 157).

(2.) In Nairnshire there are many conglomerate boulders of huge size, and angular in form, which must have been transported across what is now the Cromarty Firth from Ross-shire. They are at a height of from 400 to 600 feet above the sea. (First Rep. of Committee, p. 42.)

Other examples are afforded by the black granite boulders at Appin and in Loch Creran. Specimens of these are now on the table. As the present Report gives a full explanation regarding these boulders, I do not require to repeat how, when these specimens were submitted to Professor Judd of London, who has made the igneous rocks of the West Highlands a special study, he gave his opinion that there was no rock of the same description on the mainland, and that it was to be found only in Mull. From that island, therefore, these boulders must have been transported, and across a sea, which even now has at one place a depth of 100 fathoms, but which transportation probably took place at a period when the sea stood hundreds or even thousands of feet above its present level, or when the land sat that much lower in the ocean.

(3.) If Professor Judd's opinion of the Loch Creran and Appin boulders be correct, it goes far beyond an explanation of the boulders in these localities. For example, the Island of Lismore, whose rocks are entirely limestone, has on it many boulders of granite, which probably also came from Mull, inasmuch as Lismore lies between Mull and Appin (Com. 2d Rep., p. 157). In Lochaber there is the hill called Craig Dhu, about 2000 feet in height, so called, I believe, from the great number of black granite boulders resting on and near its top. These boulders, on account of their peculiar colour as well as position, attracted the notice of Professor Nicol and Mr Jamieson; and they are mentioned in both of my recent papers "On the Parallel Roads." (See also Committee's First Report, p. 39.)

In these papers I had occasion to point out how the position of the boulders both in Glen Roy and Glen Spean indicated that they

had come—not *down* these glens, but *up* the glens. If the boulders at Loch Creran were rafted on ice from Mull by a sea current flowing eastward, the position of the boulders in Glen Roy and Glen Spean could be explained in the same way.

(4.) There is another fact connected with the position of boulders in the West Highlands, and indeed over Scotland generally, which receives explanation from Professor Judd's paper "On the Ancient Volcanoes of the Hebrides," I mean the high position of many large boulders.

In the Committee's Second Report notice is taken of a remark by the Ordnance Surveyors (p. 157), that in the Strathcrrick district, where the highest hills are about 2900 feet above the sea, the boulders on the sides of these hills extend down to a level of about 2250 feet, *but not lower*.

In Fortingall parish (Perthshire) a gneiss boulder, weighing above 400 tons, is lying on clay slate rocks at a height of 2500 feet, being very near the ridge of clay slate hills. The gneiss hills form a range about 20 miles to the north and north-west. (Committee's First Report, p. 49.)

On the Fannoch Mountains (Ross-shire) a gneiss boulder of about 130 tons weight lies on a water-shed at a height of 2000 feet above the sea. (Committee's First Report, p. 49.)

On Schehallion (Perthshire) blocks of grey granite are seen at a height of 3000 feet. (Committee's Second Report, p. 173.)

On the top of a hill in Lochaber, exceeding 3000 feet above the sea, there are granite boulders. (Paper on Parallel Roads, Tr. of Soc. vol. xxvii. p. 740.)

Now where are there at present in Scotland ranges of mountains from which fragments could have been transported to such heights as those above named? There are now none such. Isolated peaks there are, but none exceeding 4300 feet; and of these there is but one, in the West Highlands (Ben Nevis), though it is from the westward that the great bulk of the boulders which overspread Scotland have come. Professor Judd's paper, giving reasons for believing that there were in Pliocene times mountains in Skye, Mull, Ardnamurchan, and even in Rum, some of which reached to a height of at least 14,000 feet, solves the difficulty, and explains many other curious facts besides.

For example, there is a series of granite boulders containing unusually large crystals of quartz, felspar, and mica, which occupy the straths between Fort-William and Kingussie. A boulder near Fort-William is 1500 feet above the sea, and from its position appears to have necessarily alighted on the hill from the westward (Committee's 2d Report, p. 161–2). If the sea stood at 2000 feet or more above the present level, the valleys of Lochaber and the Spey would be occupied by sea, and through them a current could flow from the ocean on the west to the ocean on the east. The summit level now between Lochaber and Strathspey is 850 feet above the sea, so that if the climate at that time was such as to allow of glaciers among the mountains and of floating ice on the sea, there would be means of transporting boulders from Mull to Lochaber and Strathspey.

5. There are several other instructive features connected with boulders brought out in this as well as in previous Reports.

(1.) The different shapes of boulders.

The Appin boulders are round shaped, whilst the Loch Creran boulders are angular, though the rock composing them is the same. The former are known in the district as "the round stones of Appin."

These Appin boulders are on the shore of the Linnhe Loch, through which in former times there must always have been a rapid current flowing, between the high mountains, forming the Glen-na-Albin or Great Glen of Scotland.

If icebergs then floated on the sea, these boulders must have undergone much pushing and rolling; whereas the Loch Creran boulders, being in what would then be only an arm or inlet from the main channel, would be exposed to no such friction.

In reference to the Kyle or sea strait, in what is now the line of the Caledonian Canal, the grinding to which the rocks on the sides of the valley have been subjected, is well seen at Cullochy on the north side, and at Inverfarrignig on the south side of the canal.

(2.) Another common feature presented by boulders in Scotland is, that when they are longer than they are broad, the longer axis is parallel with the direction in which the boulder had been transported. Very frequently also, when one end is sharp and the other end broad, the former points towards the direction

from which the boulder has come. On the theory of icebergs and floating ice this feature is intelligible; on any glacier or ice sheet theory it is not.

(3.) The existence of striæ on boulders, and the circumstance that these striæ are sometimes deeper at one edge than on the rest of the surface, is a new fact brought out in this last Report (page 30).

6. In several parts of the Report allusion is made to the evidence which boulders seem to afford, of the enormous denudation which there must have been in the district where these boulders are situated (pp. 4–9).

7. Notice is also taken in two districts of the West Highlands of horizontal terraces on the sides of hills, up to a height of 1800 feet above the sea.

If these are to be ascribed to sea action, as suggested in the Report, they would only show that Scotland possesses the same features in this respect as Norway, Sweden, and America, where there are horizontal terraces to even greater heights. It is only reasonable to expect that in the north of Scotland such records of the ocean should be discernible, considering the enormous beds of sand and gravel found at great heights in many of the mountains. On Schehallion (Com. 2d Rep., p. 173) there is gravel up to a height of at least 3000 feet.

In reference to the suggestion, that these terraces on the sides of mountains in the Highlands are marine, it is not unimportant to observe, that similar horizontal terraces at high levels occur also in lowland districts. Mr James Geikie, in his "Great Ice Age," refers to a series of "high level terraces of gravel and sand at Eaglesham," about 12 miles S.W. of Glasgow, the highest being 800 feet above the sea. "I have also traced them," he adds (page 248), "on the Moorfoots, up to 1050 or 1100 feet; and these, like the Eaglesham beds, seem equally to require the agency of the sea. Still farther south, high level shelves of gravel and sand have been detected by my colleague, Mr Skae, in Nithsdale, at a height of 1250 feet above the sea."

8. Lastly, may I be permitted, as there is still a wide field for farther investigation, to express a hope that the Boulder Committee may be re-appointed, and with additional labourers to carry on the

work. I will be happy to be allowed to remain on the Committee, but I wish to resign the honour of being Convener. I begin to find that I am now not able for the hill-climbing and trudging across Highland moors and morasses, which boulder-hunting requires.

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*Edinburgh, 24th May* 1878.

At a Meeting held this day, the Council re-appointed the Boulder Committee, with the addition of Dr Andrew Fleming, M.D.; William Jolly, Inspector of Schools, Inverness; and Ralph Richardson, Secretary of the Edinburgh Geological Society; and agreed to express a hope, that Mr Milne Home would continue Convener of the Committee.

The Council further agreed, that the "Remarks" by Mr Milne Home, at the Society's meeting on the 20th inst., when he presented the Committee's Fourth Report, appear in the Society's Proceedings, along with the Report.

J. H. Balfour, *Secretary.*

The Boulder Committee now consists of the following Fellows :—

Sir Robert Christison, Bart.
Sir Charles Wyville Thomson.
Rev. Thomas Brown, Edinburgh.
Dr Andrew Fleming, M.D., Edinburgh.
Professor Archibald Geikie, Edinburgh.
William Jolly, Inverness.
Dr Arthur Mitchell, M.D., Edinburgh.
Professor Nicol, Aberdeen.
Ralph Richardson, Edinburgh.
Thomas Stevenson, C.E., Edinburgh.
David Milne Home, LL.D. (*Convener*).

Plate I.

Fig. 1 Boulder at Glenelg.

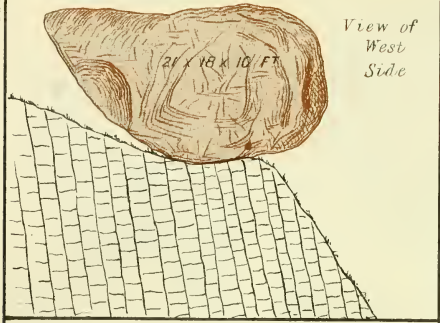



Fig. 2 Boulder at Glenelg.

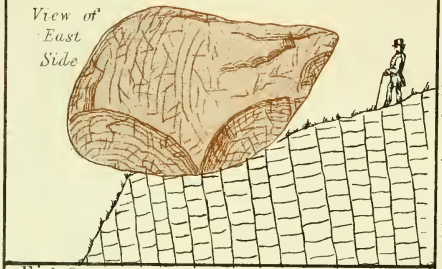



Fig. 3 Boulder at Fas-na-Cloich, Loch Creran.

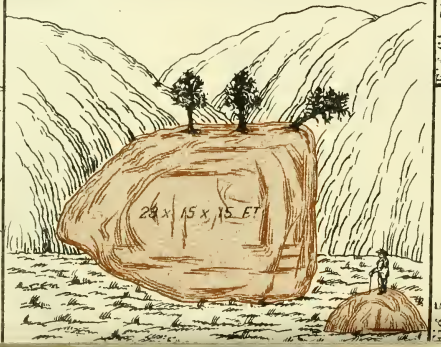



Fig. 4 Glen Rossdale.

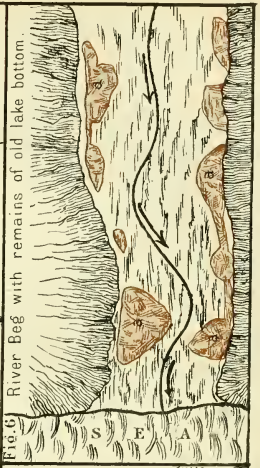




Fig. 6 River Beg with remains of old lake bottom.

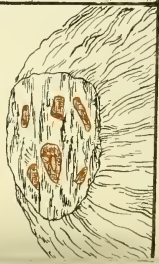


Fig. 5 Glen Rossdale. Boulders on Hill top.

Fig.3

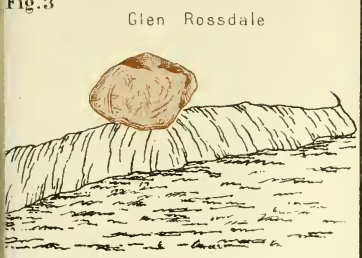



Fig.13

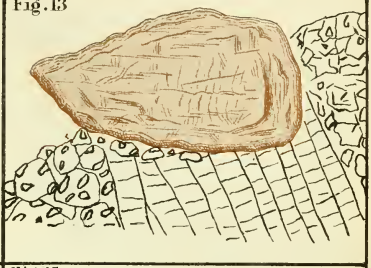


Fig.14

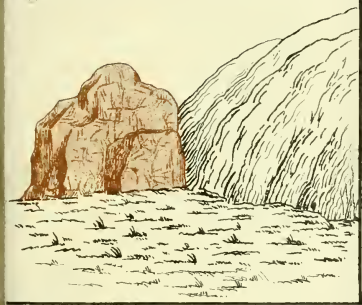


Fig.15

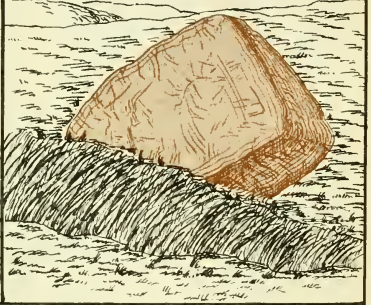
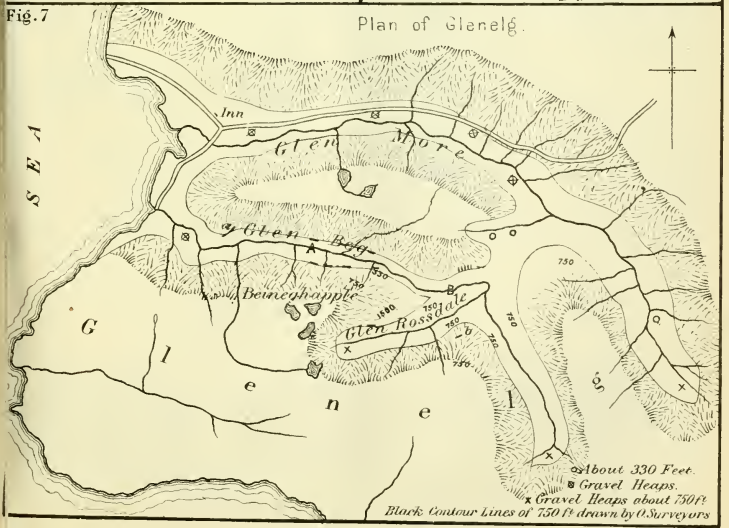


Fig.7




W & A K JOHNSTON EDINBURGH

Boulders lying on a Moor on West side of Loch Lomond

Fig.12

Fig.9 Boulder Islay intercepted by a hill

Fig.10

Boulder, Kerrera, intercepted by rock & gravel cliff on S.E side

Fig.16 Joints in rocks, smoothed by agent from West. Joints facing East rough. (Loch Tay)

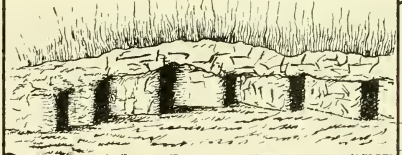


Fig.17. Glen Dochart, Rock 1386 Ft above Sea. Grooved & smoothed on West side.

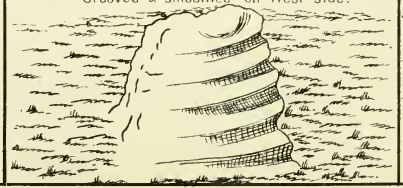


Fig.11

Boulder, Loch Lomond

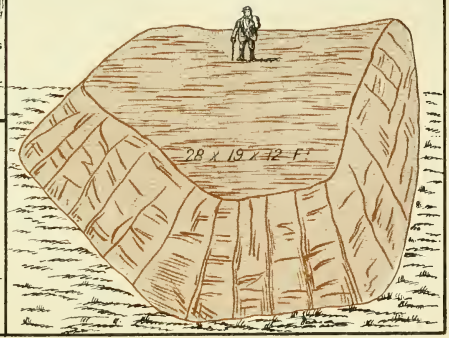



Plate III

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